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Cost-effectiveness of non-surgical periodontal therapy for patients with type 2 diabetes in the UK

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Abstract

Aim: Periodontal therapy has been shown to reduce glycated haemoglobin in patients with diabetes, although considerable uncertainty remains regarding the sustainability of such changes. We evaluate the cost-effectiveness of non-surgical periodontal therapy and rigorous maintenance treatment in patients with type 2 diabetes and periodontitis from a provider perspective in the UK.

Method: Lifetime costs relating to periodontal treatment were modelled for a cohort of patients with type 2 diabetes. The projected lifetime impact of changes in glycated haemoglobin on diabetes treatment costs and quality adjusted life expectancy were estimated from a published simulation model. Costs and outcomes were combined to estimate the Incremental Cost-Effectiveness Ratio for periodontal therapy in patients with type 2 diabetes.

Results: The Incremental Cost-Effectiveness Ratio was £28,000 per Quality Adjusted Life-Year for a man aged 58 with glycated haemoglobin of 7-7.9%. The results were particularly sensitive to assumptions on the impact of periodontal therapy on glycated haemoglobin, the proportion of patients who comply with maintenance therapy and the proportion of compliant patients who respond to treatment.

Conclusion: Assuming improvements in glycated haemoglobin can be maintained, periodontal therapy may be cost-effective for patients with type 2 diabetes at acceptable cost-per-Quality Adjusted Life-Year thresholds in the UK.

Clinical Relevance

Scientific rationale for the study

Clinical evidence indicates a link between periodontal disease and elevated blood glucose levels. Systematic review of interventions to control periodontal disease suggests they may be effective in lowering blood glucose levels. We model the potential cost-effectiveness of non-surgical periodontal treatment in patients with diabetes.

Principal findings

If reductions in blood glucose from successful periodontal treatment are maintained the resulting health benefits may be sufficient to justify the cost of treatment at commonly accepted cost-effectiveness thresholds.

Practical implications

Assessment and control of periodontal disease should be included in treatment guidelines for patients diagnosed with diabetes.

Introduction

There is growing evidence of a link between inflammation of the periodontium and raised glycated haemoglobin levels in patients with type 2 diabetes mellitus (T2DM) (Chapple & Genco, 2013). Prevalence of periodontal disease is higher in patients diagnosed with T2DM (Garcia et al. 2015; Apoorva et al. 2013). Chronic periodontal infection and the resultant inflammatory response may increase levels of glycated haemoglobin or HbA1c, a measure of long-term blood glucose levels (Borgnakke et al. 2013). The potential consequences of long-term raised HbA1c levels may be severe - micro and macro vascular complications leading to increased cardiovascular risk, blindness, amputations, renal failure and premature death (Nathan, 1993).

Approximately £8.8 billion was spent on the treatment of T2DM in 2010/11 (Hex et al. 2012). Clinical guidelines for management of T2DM include recommendations for patient education, blood pressure management, blood glucose management and management of complications such as gastroparesis, neuropathy, and renal disease, but make no mention of periodontal disease (National Institute for Health and Care Excellence, 2016). These guidelines are based on assessment of the clinical and cost-effectiveness of interventions to control circulating blood sugars and other cardiovascular risk factors, and interventions to manage the symptoms of T2DM.

The clinical evidence linking HbA1c and periodontal disease in T2DM patients suggests a role for treatment of periodontal disease in the management of T2DM (Botero et al. 2016; Faggion et al. 2016). However, control of periodontal disease requires a lifetime maintenance programme which is not cheap (Martin et al. 2014). Whilst treatment of periodontal disease can manifestly improve oral health, the impact on general health related quality of life (QOL) remains to be demonstrated. This study evaluates the cost-utility of non-surgical periodontal therapy for patients with periodontal disease newly diagnosed with T2DM. Cost-utility studies are a subset of cost-effectiveness studies in which the measure of effectiveness is a utility measure (in this case Quality Adjusted Life-Years or

QALYs [Vergel & Sculpher, 2008]). We draw on existing evidence of the impact of periodontal therapy in arresting tooth loss and on HbA1c levels. We utilise a clinical model of T2DM to estimate the impact of periodontal therapy on costs and QOL relating to T2DM. The resultant estimates of cost-effectiveness are compared against thresholds considered acceptable in the UK (McCabe et al. 2008).

Methods

A spread-sheet model was constructed to estimate the lifetime costs and consequences of periodontal therapy for a patient with newly diagnosed T2DM and periodontal disease not previously receiving regular periodontal maintenance. The model included the impact on health care costs and QOL of a decrease in HbA1c attributable to periodontal treatment. The model allowed determination of the overall increased cost of treating periodontal disease in patients with T2DM per unit improvement in quality adjusted life expectancy. We compared non-surgical periodontal treatment and lifetime maintenance treatment with no treatment of periodontal disease in patients with periodontal disease and newly diagnosed T2DM. In the treatment scenario, the dentist provides scaling and root planing and the patient commences lifetime maintenance therapy with re-treatment where necessary. In the no-treatment scenario the patient receives only a routine scale and polish as part of regular dental care.

In the base case we considered patients with life expectancies of 28, 17 and 8 years at diagnosis, corresponding to a male (female) aged 46 (49), 58 (61) or 69 (72), respectively. These life expectancies reflect typical ages at diagnosis in the UK and resulting life expectancy assuming T2DM reduces life expectancy by 7 years (Morgan et al. 2000). Guided by the reporting of results from diabetes models, we considered patients with baseline HbA1c in three ranges: 7-7.9%, 8-8.9%, and 9-9.9%.

Lifetime costs for each patient cohort were estimated as the cost of any periodontal treatment (including maintenance therapy) plus the cost of replacing teeth lost because of periodontitis plus the cost savings (negative costs) arising from any improvement in HbA1c. Gains in QOL were accrued from sustained improvement in HbA1c and quantified in QALYs. Dental costs were discounted at a rate of 3.5% per year following good practice recommendations. Costs and QALY gains associated with a change in HbA1c which were derived from published sources were already discounted. Discounting future costs and benefits reflects societal time preference to bring forward consumption and delay payment.

Results are reported as Incremental Cost-Effectiveness Ratios (ICERs). An ICER is derived by calculating the difference in costs between treatment and control and dividing by the difference in outcomes, and represents the efficiency of the intervention in generating health gains (Detsky & Naglie, 1990). The resulting cost per QALY can be compared with accepted thresholds - in the UK, health care interventions delivering additional QALY gains at less than £20,000 to £30,000 per QALY are considered cost-effective (McCabe et al. 2008).

Effectiveness of non-surgical periodontal treatment

We assumed periodontal therapy is delivered in two 60 minute sessions by a practitioner with experience of undertaking periodontal treatment in primary care. Regular maintenance therapy then commences consisting of a 30 minute hygienist appointment every 3 months. We assumed the patient would require retreatment for periodontal disease once every 3 years, which could be provided at the patient's primary practice in a 60 minute session. Compliance with maintenance therapy of 11-70% of patients has been reported (Ramseier et al. 2014; Pretzl et al. 2009; Fardal et al. 2003). We assumed 30% compliance and examined a range of values in sensitivity analysis. We assumed that non-compliant patients would incur the costs of initial treatment only, and would gain no health benefits. We assumed that 87% of compliant patients would respond well to treatment and be able to maintain their periodontal health (Lorentz et al. 2009). The remaining 13% were assumed to incur the full cost of treatment and maintenance therapy and gain no health benefits.

Rates of tooth loss of 0.01 to 0.28 teeth a year have been reported in patients undergoing treatment including maintenance for periodontal disease (Ng et al. 2011; Martin et al. 2010; Martin et al. 2009; Fardal et al. 2004; Nabers et al. 1988; Hirschfield & Wasserman, 1978). The large variability has been ascribed to differences in disease severity across studies (Martin et al. 2010). We used a rate of 0.036 teeth lost per year due to periodontal disease in a patient population mostly compliant with maintenance therapy (Fardal et al. 2004). Data on tooth loss in patients with untreated periodontal disease have been reported (Martin et al 2014). These data indicate a mean rate of 0.19 teeth lost per year for patients with moderate or high risk factors, representative of a population with T2DM.

The impact of periodontal treatment on HbA1c has been the subject of a number of recent reviews and meta-analyses (Botero et al. 2016; Faggion et al. 2016). There is consistent evidence of an absolute decrease in HbA1c over shorter follow-up (typically 3 months) ranging from -0.24% (Wang et al. 2014) to -1.03% (Sun et al. 2014) with most studies reporting decreases in the range -0.3 to -0.5%. We selected a conservative estimate from a robust Cochrane review and meta-analysis (Simpson et al. 2015). That study reported an absolute decrease of -0.29% at 3-4 months, a decrease similar to that observed from engagement in moderate exercise (Umpierre et al. 2011). Evidence of a sustained decline in HbA1c is weaker; at six months estimates from meta-analyses range from 0.02% (Simpson et al. 2015) to -1.18% (Sun et al. 2014). We assumed that the absolute decrease in HbA1c of -0.29% observed at 3-4 months is sustained for the subgroup of patients who comply with maintenance treatment *and* respond to periodontal therapy.

Simulation models from the UK (DiabForecaster; McEwan et al. 2006) and the US (CORE; Palmer et al. 2004) have estimated the impact of reductions in HbA1c on lifetime costs of diabetes management and quality adjusted life expectancy. We used results from DiabForecaster to estimate the impact of a decrease in HbA1c on costs and quality adjusted life expectancy (Table 1). DiabForecaster costs were inflated to 2014/2015 values using the Hospital and Community Health Services Index (Curtis & Burns, 2016).

Costs

We took a provider perspective and considered costs falling on health care and dental care providers. In the UK, publicly funded dental primary care is provided by contractors and remunerated according to Units of Dental Activity (UDAs) which are predetermined by procedure. Payment for UDAs is negotiated with the local health authority, but is typically £25 per UDA (British Dental Association 2013). In addition, around half of adults make a co-payment which is tiered according to the complexity of the procedure. Periodontal treatment would attract three UDAs. We considered it unlikely that £75 would cover the costs to the provider. We estimate the true costs to the provider but note costs to the public sector are lower. In a sensitivity analysis we exclude costs borne by the patient through co-payments.

Dental care costs were calculated on the basis of clinician time to provide the treatment. Hourly rates were taken from an authoritative source and include the cost of all overheads, training and qualifications (Curtis & Burns, 2016). For periodontal treatment we applied the unit cost of £207 per hour of patient contact time for a providing-performer (practice partner); this assumes a salary of £116,700 reflecting specialist experience and includes associated practice costs such as dental nurse, receptionist and office costs. For restorative treatment following tooth loss we applied the unit cost for a performer only (employee); this assumes a salary of £60,600. However, we modified this cost to include the same associated practice costs as those given for a provider-performer, generating a unit cost of £167 per patient contact hour. We assumed the same hourly cost for a hygienist as a nurse on band 5 of the National Health Service Agenda for Change pay scale (£56). Procedure times for tooth extraction, provision of removable dentures and resin-bonded bridges were taken from Pennington et al. (2011). Laboratory costs for prosthetic replacements were also included. In 2015/16, patient co-payments were £51.30 for a band two procedure which includes each course of periodontal treatment, each scheduled maintenance visit, and tooth loss with no replacement. The co-payment was £222.50 for a band three procedure which covers tooth loss with prosthetic replacement. Patient co-payments were multiplied by 0.58 representing the proportion of all UDAs provided in the UK in 2015/16 for band two and band three treatments for which the patient was ineligible for a co-payment waiver (Health & Social Care Information Centre, 2016). The data is summarised in Table 2.

We assumed the following prosthetic replacements for lost teeth based on data reported by Pennington et al. (2011): 45% resin-bonded bridge, 40% removable partial denture, 15% no replacement (gap). This generated a mean cost for tooth loss of £295 in total, and £181 net of patient co-payments.

Sensitivity analysis

Univariate sensitivity analysis was undertaken on all model parameters. Ranges were selected for each parameter based on published confidence intervals, where available, or on the range of values published. Table 3 reports the minimum and maximum values considered for each parameter. Minimum periodontal treatment and re-treatment costs were estimated using the unit cost for a performer only dentist (£167); maximum costs were estimated as NHS tariffs for treatment in secondary care. The range of values for maintenance costs was generated by varying treatment times from 40 to 240 minutes a year representing minimum and maximum values reported in Pennington et al. (2011). The range of values for tooth loss in patients complying with and responding to treatment was taken from Pennington et al. (2011) after assuming the minimum (40 minutes) and maximum (240 minutes) total annual maintenance times reported therein. The upper value for tooth loss in the absence of successful periodontal treatment is that reported for Sri Lankan tea plantation workers (Löe et al. 1986), a population likely to have had high rates of diabetes; the lower value was taken from a US study (Becker et al. 1979). The lower value for the mean cost of replacing lost teeth was derived by assuming 25% of patients receive a resin-bonded bridge, 25% a removable denture and 50% no replacement (gap); the upper value was derived by assuming the highest reported time taken for resin-bonded bridges (200 minutes) and removable dentures (145 minutes) in Pennington et al. (2011). Results are reported in the form of a tornado plot and based on a patient with life expectancy of 17 years and an initial HbA1c level of 7-7.9%. Sensitivity analysis was also undertaken in which costs falling on patients through co-payments were excluded.

Results

Table 4 reports the results of the base case analysis. Cost savings from reduction in HbA1c, and from reductions in tooth loss following periodontal treatment, are modest. After including these savings, total cost in the treatment arm remains higher than the control. QALY gains are also modest after assuming most patients fail to comply with maintenance treatment and gain no benefits. Dividing the incremental cost by the incremental QALY gain for each subgroup generates ICERs ranging from £11,000 to £35,000. The intervention is more cost-effective in patients with higher HbA1c for whom DiabForecaster predicts larger health gains. The intervention is also more cost-effective in older patients for whom lifetime costs of periodontal treatment are lower. The model assumes health gains from a reduction in HbA1c are independent of age; in reality, these health gains are likely to decrease with age. This will attenuate the variation in the ICER across age groups. The ICER is below £30,000 per QALY for all subgroups except the youngest age groups with initial HbA1c 7-8.9%.

The results of one-way sensitivity analysis on each of the parameters are displayed in Figure 1. The bars show the extent of variation in the ICER as each parameter is varied over the range specified in Table 3. The figure illustrates the considerable uncertainty surrounding the results. The results are most sensitive to the reduction in HbA1c associated with successful periodontal treatment, the proportion of patients complying with treatment and the proportion of compliant patients who respond to treatment. The results are least sensitive to uncertainty in the general health cost savings associated with a decrease in HbA1c, the cost of replacing lost teeth and the mean tooth loss rate in compliant patients who respond to treatment.

The exclusion of patient copayments from overall costs reduced both periodontal treatment and restorative dentistry costs and had very little impact on the overall incremental treatment costs or ICERs.

Discussion

Our analysis indicates periodontal treatment increases the overall costs associated with the management of periodontal disease. The cost savings arising from reduced tooth loss are modest when set against lifetime periodontal treatment and maintenance costs. However, the health benefits attributable to reductions in HbA1c in patients with T2DM are sufficient to justify the additional costs in the majority of patient subgroups we examined. For a typical 58 year old diagnosed with T2DM and with HbA1c in the range 7-8.9% the ICER was £26,000–28,000 per QALY, below the accepted threshold of £30,000 per QALY. These estimates derive from fairly modest lifetime gains of 0.12-0.17 QALYs in compliant patients achieving control of their periodontal disease. Our analysis ignored any potential oral health benefits (Al-Harthi et al. 2013). Methods to quantify the QALY gains from dental treatments are insufficiently developed to facilitate inclusion in our analysis. However, a disability weight (reduction in quality of life) of 0.008 for periodontitis was estimated in the Global Burden of Disease Study (Salomon et al. 2010), and severity of disease is linked to worsening outcomes (Buset et al. 2016).

Our findings are subject to considerable uncertainty. The largest uncertainty is associated with the decrease in HbA1c attributable to periodontal treatment. There is considerable, additional uncertainty regarding the duration of any gains in HbA1c following periodontal treatment. Our findings are wholly dependent on the assumption that short term gains in HbA1c following treatment of periodontal disease are maintained, provided maintenance treatment is successful.

This assumption appears biologically plausible, but there is insufficient long term data to conclusively demonstrate it. Of course, periodontal treatment may still be justified by oral health improvements. But the argument that periodontal treatment is cost-effective based on improvements in HbA1c control rests on the assumption that short term gains are maintained.

Further studies are required to quantify the longer term impact of periodontal treatment on HbA1c control in patients with diabetes. However, the accumulated evidence indicates a role for periodontal treatment in the management of diabetes. Our analysis strengthens this argument in demonstrating the potential for periodontal treatment to be cost-effective on the basis of reductions in HbA1c, before consideration of the oral health benefits. The case for including periodontal health in the clinical guidelines for the management of T2DM is strengthened. However, guideline changes may be ineffective if patients face barriers in accessing periodontal treatment. The current UDA tariffs for periodontal treatment are unlikely to cover the cost to providers, and may incentivize significant under treatment. They should be reviewed.

Comparisons with the literature

To our knowledge this is the first cost-utility analysis of periodontal treatment. The extant literature consists of cost-effectiveness analyses and cost-minimisation studies. An early cost-effectiveness analysis compared surgical and non-surgical treatment using Quality-Adjusted Tooth Years (Antczak-Bouckoms & Weinstein, 1987). The study showed non-surgical treatment was more effective and less costly than surgical treatment. Heasman and colleagues (2011) examined the cost-effectiveness of systemic and adjunctive anti-microbials as part of maintenance care in terms of the cost per mm of attachment loss avoided (whole mouth). Systemic antimicrobials were cost-effective for patients prepared to pay between £843 (2009 GBP) and £1,761 to avoid one mm of attachment loss, and Minocycline gel was cost-effective for those prepared to pay more. Pennington and co-workers (2011) compared the cost-effectiveness of supportive periodontal care in state, private and specialist practices in eight countries. Care in a specialist setting was cost-effective for patients prepared to pay $300-2,250 (2009 USD) per tooth-year and $1,450-13,150 per mm attachment loss avoided.

Two cost-minimisation studies have examined costs in the presence or absence of periodontal treatment. Fardal and coworkers (2012) projected costs and tooth loss over 33 years for patients receiving periodontal therapy of $9,500-10,000 (2009 USD) and 1.19 teeth. No periodontal treatment cost more if tooth loss exceeded 4.5-4.9 teeth over 16.5 years (0.27-0.30 per year) assuming lost teeth were replaced with bridgework costing $2,429. Martin and colleagues (2014) compared tooth loss over 13 years in 776 patients undergoing periodontal treatment with 523 US military veterans matched on severity and risk who had not received periodontal treatment. Assuming replacement of lost teeth with bridgework costing $3,416 (2011 USD), periodontal treatment was cost saving for patients with moderate or severe disease. We found that periodontal treatment costs were only partially offset by savings in restorative dentistry costs. However, we applied a considerably lower cost of £295 for tooth replacement reflecting typical restorative costs in UK publicly funded practice.

Strengths and limitations of the analysis

Our analysis utilised the best available evidence on the impact of periodontal treatment on HbA1c levels. Unit costs were estimated on the basis of hourly costs for dentists and hygienists derived from an authoritative UK source and current lab-work charges. We utilised a well-recognised model for estimating the long term costs and consequences of reductions in HbA1c. We made conservative assumptions regarding the proportion of patients complying with maintenance therapy and the impact of foregoing maintenance therapy. We also chose conservative estimates of tooth loss in the absence of treatment.

Our analysis is subject to a number of limitations. First and foremost we have assumed that beneficial impacts of periodontal treatment on HbA1c levels are maintained for the remainder of the patients' lifetimes provided periodontal disease control is maintained. We used a simple modelling approach, and while we have quantified the impact of individual parameter uncertainty we have not undertaken a probabilistic analysis which would have conveyed the joint impact of parameter uncertainty. Our ability to explore differences across patient subgroups was limited. The published results from DiabForecaster do not differentiate by age. Hence, we had to apply the same cost savings and QALY gains from improved HbA1c control to each of the three age subgroups in our analysis. This assumption is likely to magnify differences in cost-effectiveness across age groups. Our analysis ignores any oral health benefits of improved periodontal disease control, an omission likely to underestimate the cost-effectiveness of periodontal treatment. We have not explicitly considered the impact of periodontal treatment on the costs of managing patients with extensive suppuration; if effective periodontal treatment mitigates these costs then our analysis will have underestimated cost-effectiveness. Treatment costs are estimated in a UK setting which may limit the transferability of findings across jurisdictions.

Conclusions

The beneficial effect of treating periodontal disease on HbA1c alone may be sufficient to justify treatment in patients with T2DM at accepted cost-effectiveness thresholds in the UK. Given the additional oral health benefits and high prevalence of periodontal disease in T2DM patients there is a strong case for inclusion of periodontal assessment and treatment in clinical guidelines for the management of T2DM.

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Tables

Table 1: DiabForecaster predictions of Quality Adjusted Life-Year gains and costs saved for a 1% absolute decline in HbA1c

Absolute change in HbA1c (%)	QALY gain[a]	Costs saved in 2004/2005 GBP[b]	Costs saved in 2014/2015 GBP[c]
8 to 7	0.4	600	757
9 to 8	0.4	1200	1514
10 to 9	0.6	1600	2019

QALY – Quality Adjusted Life-Year. [a]Discounted at 1.5%. [b]Discounted at 6%. [c]Inflated using the Hospital & Community Health Services inflation index.

Table 2: Estimated costs of dental care

Procedure	Duration (minutes)	Labour cost (£)	Labor-atory cost (£)	Total cost (£)	Patient copay (£)	Total cost less patient copay (£)
Initial periodontal treatment	120	414	0	414	30*	384
Periodontal re-treatment	60	207	0	207	30*	177
Periodontal maintenance (per visit)	30	28	0	28	30*	-2
Extraction	20	56	0	56	30*	26
Resin-bonded Bridge	80	223	75	298	129*	169
Removable partial denture	100	278	100	378	129*	249

copay – copayment. *Copayment band charge multiplied by proportion of eligible patients

Table 3: Parameter ranges used in univariate sensitivity analysis (Figure 1)

Parameter	Min value	Base value	Max value
Initial periodontal treatment costs (£)	334	414	800
Periodontal maintenance costs (£ per year)	37	112	224
Periodontal re-treatment costs (£ per visit)	167	207	400
Frequency of re-treatment (years between treatment)	2	3	5
HbA1c decrease with successful periodontal treatment (%)	0.1	0.29	0.48
QALY gain for 1% decrease in HbA1c	0.3	0.4	0.5
Diabetes treatment savings for 1% decrease in HbA1c (£)	568	757	946
Proportion of patients complying with treatment	0.11	0.3	0.45
Proportion of compliant patients responding to treatment	0.5	0.867	0.95
Yearly tooth loss, compliant and responsive patients	0.01	0.036	0.11
Yearly tooth loss, untreated/noncompliant/non-responding patients	0.1	0.19	0.36
Average cost of tooth replacement (£)	197	295	488

Min – Minimum. Max - Maximum

Table 4. Costs and Incremental Cost-effectiveness Ratios for patient subgroups in the base case.

Age	HbA1c (%)	Costs of perio treat (£) interv	Costs of tooth loss (£) interv	T2DM costs after treat (£)	Total costs (£) interv	Costs of tooth loss (£) control	Incre-mental costs (£)	Incre-mental QALYs	ICER* (£)
46	7-7.9	1,329	809	-£57	2,081	1,024	1,056	0.030	35,023
	8-8.9	1,329	809	-£114	2,024	1,024	999	0.030	33,131
	9-9.9	1,329	809	-£152	1,986	1,024	961	0.045	21,425
58	7-7.9	1,052	579	-£57	1,574	734	840	0.030	27,850
	8-8.9	1,052	579	-£114	1,517	734	783	0.030	25,958
	9-9.9	1,052	579	-£152	1,478	734	745	0.045	16,463
69	7-7.9	740	315	-£57	998	399	599	0.030	19,858
	8-8.9	740	315	-£114	940	399	542	0.030	17,965
	9-9.9	740	315	-£152	902	399	504	0.045	11,135

perio – periodontal; treat – treatment; interv – intervention; T2DM – type 2 diabetes; QALYs – Quality Adjusted Life-Years; ICER – Incremental Cost-Effectiveness Ratio *The ICER is calculated by diving the incremental health gain (QALYs) by the incremental cost to generate a cost per unit gain in health (QALYs).

Figures

Figure 1. Impact on the Incremental Cost-effectiveness Ratio of one –way sensitivity analysis in which each model parameter was varied across the range specified in Table 3.